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ONION DISEASES AND THEIR CONTROL

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ONION SMUT kills the young seedlings in the spring, is common in old onion sections, but can be controlled successfully by applying a formaldehyde solution in the row with the seed by means of a drip attachment on the seeder.

Onion mildew blights the leaves in midseason, but can be held in check by rotation of crops, good drainage, thorough cultivation, and by spraying the foliage thoroughly with Bordeaux mixture before the disease becomes widespread in the field.

Pink-root is a gradual decay of the roots which does not ordinarily kill the plants but so retards their development that only small bulbs or scallions are produced. Avoid diseased soil, especially for seed beds; rotate crops; use quick-acting fertilizers, if the disease appears.

Storage rots—smudge, neck-rot, soft-rot, black-mold—are controlled by protecting the crop from moisture during and after harvest and by facilitating as rapid and thorough curing as possible.

Bruising due to careless handling, topping, or milling should be avoided.

For storage a well-ventilated warehouse kept at 32° to 35° F. is preferable.

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ONION DISEASES AND THEIR CONTROL

J. C. WALKER,

Pathologist, Office of Cotton, Truck, and Forage Crop Disease Investigations, Bureau of Plant Industry

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SCOPE OF THIS BULLETIN

THE ONION INDUSTRY of the United States is widely distributed and of increasing importance. The chief producing centers may be grouped into two large divisions, namely, (1) those in the northern and central tier of States, extending from Massachusetts to the Pacific coast, which produce principally a late summer or fall crop, and (2) those in the southern tier of States, extending from Florida to southern California, in which a winter or spring crop is grown. The wide range of soil and climatic conditions in the different sections makes difficult a general discussion of onion diseases which may apply to all regions. This bulletin is written primarily from the standpoint of onion growing in the North Central and Northeastern States, viz, from Iowa to Massachusetts. Recommendations in general, however, will apply to other sections, and at certain points special reference is made to diseases in the South and West.

DESCRIPTIVE KEY TO ONION DISEASES

Since certain diseases of onions resemble one another rather closely, the following descriptive key will aid in their prompt recognition:

A. Diseases primarily important in the field.

1. Dark pustules appear within the leaves or scales and may later split open, exposing black powdery masses, principally on the young seedlings. (See fig. 1) ..... Smut, page 4

2. The leaves turn pale green and yellowish, become covered with a violet furry growth, and finally collapse; most serious in moist weather in midseason or later. (See fig. 5) ..... Mildew, page 8

3. A black, moldy growth on leaf tips or seed stalks, often following mildew ..... Leaf-mold, page 13
4. A rapid dying back from the tips of the leaves, accompanied by a rot starting at the base of the bulb. (See fig. 6) ..... Fusarium rot, page 13
5. A condition of the tops quite similar to Fusarium rot but differing in that black, round bodies about the size of poppy seeds appear in the diseased bulb ..... White-rot, page 14
6. The roots turn pink in color and die; new roots are attacked as they develop, resulting in a marked stunting of the plant ..... Pink-root, page 11
7. Orange or golden yellow pustules appear on leaves or seed stems, especially on those of Egyptian onion ..... Rust, page 14
8. Creeping or twining, leafless, plants attack leaves of onions, often killing the tops in roughly circular areas in the field. (See fig. 7) ..... Dodder, page 15
9. The leaves become a sickly green; swellings form on the roots. (See fig. 8) ..... Root-knot, page 15

B. Diseases primarily important in storage and transit.

1. A rot begins at the neck of the bulb and progresses downward; the tissue shrinks and collapses; a gray to brown moldy growth and hard, black kernels later appear on the surface of affected scales. (See figs. 9 and 10) ..... Neck-rot, page 20
2. A rot begins at harvest time or later, but differs from neck-rot in that it is softer and more watery, usually with a very offensive odor. (See fig. 11) ..... Soft-rot, page 21
3. A semiwatery rot advancing from the base of the scale upward. (See fig. 6) ..... Fusarium rot, page 13
4. Black, powdery masses form, not in definite pustules within the scales, as in smut, but on the outer surface of or between the scales. (See fig. 12) ..... Black-mold, page 22
5. Smudgy, superficial black spots made up of fine dots, but with no powdery masses appear shortly before harvest time on the outer scales; primarily on white varieties. (See fig. 13) ..... Smudge, page 23
6. A semiwatery decay, at first deep yellow, then wine red, and finally black, attacking the neck or wounds in the scales, which dry down to a papery texture ..... Macrosporium rot, page 24

In addition to these specific diseases there are certain other troubles, due to insects, with which they may be confused:

(1) Thrips injury: Small white chafed spots appear on the leaves and cause them to die prematurely; the minute pale-yellow thrips which cause the injury are commonly present.

(2) Onion maggots often kill seedlings by feeding upon the roots. This injury is sometimes confused with onion smut, but the absence of pustules of black powder distinguishes it from the latter.

DISEASES PRIMARILY IMPORTANT IN THE FIELD

SMUT

Onion smut appeared in the United States nearly 50 years ago, when it was found to be doing damage in the Connecticut River Valley, and has spread into most of the large northern onion sections, including New York, New Jersey, Ohio, Wisconsin, Illinois, Iowa, and Oregon. It does not occur in the southern onion region. When once introduced it becomes more serious each year the crop is replanted on the same soil and spreads slowly to adjoining areas.

CHARACTERISTICS OF SMUT

The disease appears soon after the seedlings come above ground. Brown to black elongated blisters form within the scales or leaves, the latter usually being slightly thickened and often curved downward abnormally. Not uncommonly the leaf splits, exposing a

powdery black mass of spores in the interior of the blister (fig. 1). Many of the young seedlings are so severely attacked that they die within three to five weeks after germination. In others, which may survive until midseason or harvest, the new leaves and scales continue to be attacked as they develop. A very few outgrow the disease. Although most of the infected bulbs are so small and imperfect that they are thrown out at harvest time, occasional ones are large enough to escape notice and thus reach the warehouse or market. Such specimens are characterized by the slightly raised brown to black pustules, most prevalent near the base of the bulbs and usually occurring as deeply as the third or fourth scale. Smut does not cause a storage rot, but smutted bulbs shrink more rapidly and are more subject to the attack of other organisms than healthy ones.

FIG. 1.—Onion smut. A young bulb showing unbroken blisters on scales and leaves. These later split open and expose the black, powdery spore masses

CAUSE OF SMUT

Smut is due to a fungous parasite (*Urocystis cepulae*) which attacks only the onion and certain closely related species of plants. The black powdery masses which are exposed upon the splitting of the blisters consist of myriads of spores, or seed bodies, which propagate the fungus. These spores fall to the soil and overwinter there, being very resistant to cold. In the spring, at the time when the onion seeds are germinating the smut spores also germinate and infect the young seedlings. Having established itself within the young plant, the fungus continues to develop, taking its nourishment from the onion seedling and again forming new spore blisters.

A peculiar and important fact about smut is that the onion plant can be attacked by the fungus only while in the young seedling stage. Recent experiments show that when the mean soil temperature is 84° F. or above during this period no infection occurs, and the plant having escaped the fungus remains free from the disease. At temperatures somewhat below that mentioned there is a greater tendency for slightly infected plants to outgrow the disease than at lower temperatures. It is probable that the absence of the disease in the South is due in large measure to these facts, inasmuch as in the southern

sections onion seed is sown in August and September, when the soil is extremely warm, while in the North it is sown in the spring, when the soil is cool. After the plants are about 3 inches high they become immune to further infection, and onion sets or onion seedlings 3 to 4 inches high transplanted to smut-infested soil will not contract the disease.

Smut spreads slowly in the soil, but an infested spot in a field will gradually become larger and more severely diseased each year onions are grown. Moreover, the spores are carried to other parts of the field on the farm implements, feet of men and animals, by surface water, and in dust carried by the air. It may also be carried into new localities on onion sets containing the disease in their outer scales. Purchasers of onion sets who have not been troubled with

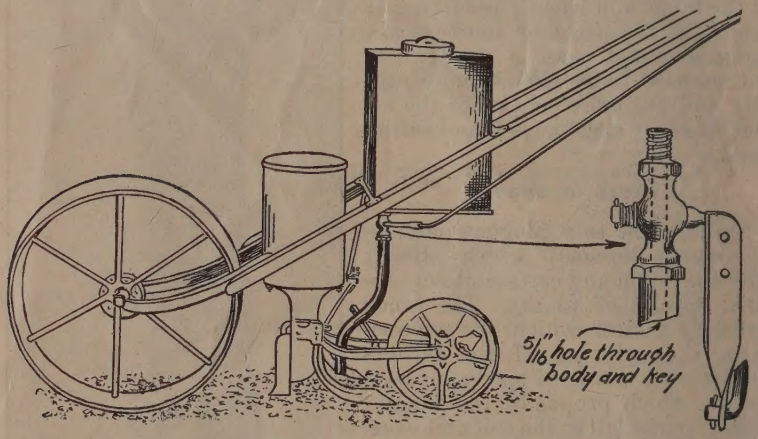

FIG. 2.—Onion seeder with a formaldehyde drip attachment for disinfecting the soil at the time of seeding, to control onion smut. The cut-off valve is regulated from the handle. (See text for description)

the smut should be on their guard lest they contaminate their soil by planting smutted sets.

CONTROL OF SMUT

Sanitary measures.—Where practicable, the tops should be burned after harvest, and care should be taken to avoid as much as possible the returning of infested onion refuse to the soil. The spreading on the fields of waste from onion warehouses is a bad practice, since it may contain smut or other diseases which may thus be introduced into healthy soil.

Use of onion sets.—Where green onions are grown for early spring markets or where an early crop of bulbs is desired, onion sets are commonly used. Since plants grown from sets are not attacked by smut, this method of propagation can be used with success on smut-infested soil.

Use of onion seedlings from healthy soil.—Within recent years northern market gardeners to some extent have practiced starting onion seedlings in the hotbed or greenhouse and transplanting to the field when 3 or 4 inches high. On southern truck farms it is the

general custom to sow the seed in beds in the fall and transplant during the winter. Where this method is profitable, onion smut can be avoided by growing seedlings on healthy soil until 3 or 4 inches high and then transplanting to the fields.

Use of formaldehyde drip.—In the large commercial onion districts of the northern States, where the use of sets or seedlings is impracticable, onion smut is controlled by the application of a solution of formaldehyde in the furrow with the seed. Since the young onion seedling is susceptible to the disease for only a short time, it is necessary to use only enough of the disinfectant to keep the fungus in check in the soil close to the seed.

Apparatus.—The apparatus for applying the formaldehyde solution consists of a galvanized iron tank with a pipe leading down to

FIG. 3.—Field of onions on smut-infested soil where formaldehyde was applied. The disease has killed a large percentage of the plants in the two untreated rows in the center, while the remainder of the field has practically a full stand

the furrow (fig. 2.) It can be made by any tinner. Such an attachment is offered for sale by certain manufacturers of onion seeders. The size of the tank will vary with the type of seeder used, but for the ordinary single-row seeder a 2-gallon tank is a sufficient load. It is best placed just behind the seed box, where the extra weight will rest mainly on the packing wheel. The pipe should be so arranged as to run the solution directly into the center of the furrow just before the packing wheel closes it, and to lead it far enough down to prevent splashing on the shoe or the packing wheel. It is essential to have a cut-off valve in the pipe which can be controlled from the handle of the seeder, enabling the operator to shut off the flow quickly at the end of a row or whenever desirable. There should be about a five-sixteenths inch flow of liquid from the tank, in order to secure the

proper quantity of 200 gallons per acre. In certain localities the attachment has been modified successfully for use with the 8-row gang seeder.

Strength and quantity of the solution.—Great care should be used in applying this treatment, since too strong a formaldehyde solution will prevent the onion seed from germinating, while too weak a solution will not hold the fungus in check. It is advantageous to increase the strength and decrease the quantity of the liquid as much as possible, in order to reduce the labor of application, but this can be done only up to a certain limit.

To each gallon of water use 1 fluid ounce of 37 to 40 per cent formaldehyde solution, sometimes known commercially as formalin.[1] Apply this diluted solution at the rate of 200 gallons per acre, or 1 gallon to about 185 feet of row.

Where several rows of seed are sown close together for the production of onion sets, the quantity of solution applied should be increased accordingly.

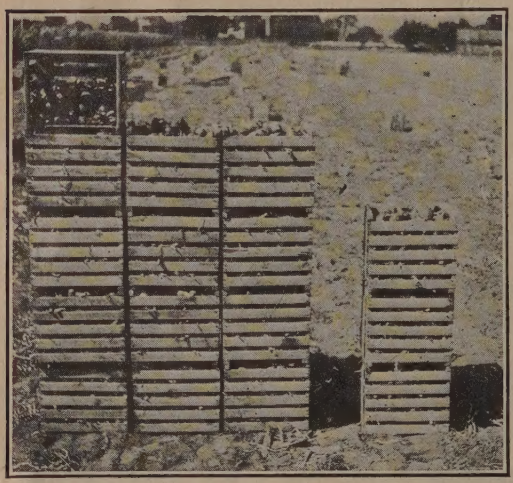

FIG. 4.—Yield of a treated and an untreated row of onions in the field shown in Figure 3. The treated rows averaged 545 bushels and the untreated ones 200 bushels per acre

Cost of application.—About 12 pounds of the 40 per cent formaldehyde solution are required for each acre, which, when purchased in wholesale quantities, can be obtained at about 8 cents a pound (1922 prices). When a single-row seeder is used, the labor required at the time of sowing is about doubled, bringing the entire cost of application to about $3 an acre. This is a very significant cost compared with the financial return from the operation. (See figs. 3 and 4.)

MILDEW (BLIGHT)

The first symptoms of onion mildew, or blight, may be found by examining the leaves closely on a dewy morning, when a violet furry covering may be seen on the outer surface. Within a day or two the leaves become pale green and finally yellowish, the furry growth becomes more widespread, and the diseased portions of the plant eventually collapse (fig. 5). The disease commonly starts in the field in spots and spreads to the surrounding areas, its development being greatly aided by moist weather. If the weather remains dry following an outbreak of the disease, the plants send out new leaves and

[1] For larger quantities 1 pint to 16 gallons gives the same dilution.

partially recover. However, on the return of damp conditions the fungus revives and the new growth becomes blighted. The killing of leaves in this manner, although it may not entirely kill the plants, reduces growth, and the bulbs remain small.

The onion mildew has been reported from most States where onions are grown extensively. The destructiveness of the disease, however, varies widely in different localities and in different years in the same region. As in the case of a number of other downy mildews, prevailing moist weather is absolutely essential for its development in epidemic form. Heavy losses have been reported in New York, Michigan, Oregon, California, and Louisiana. In the two States last mentioned the chief damage is to the seed crop, the heavy fogs which are very prevalent being especially favorable for the development of the mildew, which attacks the seed stalks, causing them to fall over before the seed is mature.

FIG. 5.—Onion mildew (blight). Note the fungous growth on the dying lower leaves; the two youngest leaves are still healthy. The spread of the disease to new leaves depends on the amount of moist weather prevailing. (Photographed by the Vermont Agricultural Experiment Station)

CAUSE OF MILDEW

Mildew is caused by a fungus (*Peronospora schleideni*) and belongs to the class of downy mildews, among the most important of which are late-blight of potato, grape mildew, and cucumber mildew. The furry masses on the affected leaves are branches of the fungus, which bear an abundance of spores. These spores are very light and are easily carried by the wind to healthy plants. However, they are short lived and very sensitive to drying.

In damp weather drops of water on the plant furnish sufficient moisture for prompt germination of the spores. The resulting fungous growth enters the plant and absorbs food from it, thereby causing its leaves to shrivel and die. The fungus thus nourished produces more spores, which in turn are wind-borne to healthy plants, where under favorable conditions they again produce the disease.

In the fall the fungus forms in the diseased leaves thick-walled winter spores which are resistant to drought and cold. They germinate in the spring and again start the disease in the new crop. It is also by means of these winter spores that the mildew may be spread from diseased fields to healthy fields in infested soils, in diseased onion tops, or in sets.

CONTROL OF MILDEW

Sanitation and cultivation.—The successful control of onion mildew depends largely on attention to cultural and sanitary measures. Since many of the winter spores live over in dead tops, it is advisable to rake these and burn them in the fall. Thorough cultivation is essential in order to keep the crop as vigorous as possible, so that it may rapidly outgrow the disease when the latter is checked by dry weather.

Rotation of crops.—Since the winter spores live over in the field, it is advisable to plant infested fields to other crops for a few years. It is not known how long the fungus can live in the soil, but it will certainly be greatly reduced in two or three years. It is true that many growers prefer to grow onions for a number of years successively on the same soil. However, it is no doubt true that a number of other cultivated crops yield high enough returns to be considered in a rotation, especially when the general benefits of a three or four year rotation are considered. In certain sections farmers, realizing the importance of this practice in the control of diseases, are successfully rotating onions with cabbage, potatoes, and sugar beets, and in some cases grain is included.

Air and soil drainage.—Inasmuch as moist conditions greatly favor mildew, care should be taken to select fields where the air drainage is good, so that excessive dew and fog may be avoided. Good soil drainage also helps to reduce blight, since it reduces the moisture in the air near the surface of the soil.

Spraying for mildew.—In the control of onion mildew, Bordeaux mixture applied as a spray has been used to some extent, but not with complete success in all cases, since there is considerable difficulty in making the spray stick to the leaves. If spraying is to be done, rosin-fishoil soap should be added to the spray mixture to make it adhere to the leaves. The spray should be applied thoroughly before the disease has become established in the field, and it may be necessary to spray the field several times during the summer, especially during the rainy season.

PREPARATION OF BORDEAUX MIXTURE[2]

In the preparation of Bordeaux mixture the ingredients should be used in the following proportions:

Copper sulphate	4 pounds.
Quicklime	4 pounds.
Rosin-fishoil soap	3 pounds.
Water to make	50 gallons.

[2] The section on Bordeaux mixture was prepared by Mr. W. B. Clark.

Where Bordeaux mixture is to be used frequently and in reasonably large quantities, it is more convenient to make up the ingredients in concentrated stock solutions or suspensions, since these can be kept on hand indefinitely if water lost by evaporation is replaced.

Stock solutions and suspensions.—Build an elevated platform to hold the barrels, preferably near a well or other source of water. Suspend 50 pounds of copper sulphate, inclosed in burlap or a loosely woven sack, so as just to dip into a 50-gallon barrel of water. Slake 50 pounds of lime in another barrel and dilute to 50 gallons with water. Place 37½ pounds of rosin-fishoil soap in a barrel and slowly add water to make 37½ gallons, *stirring constantly to avoid the formation of lumps.* These stock solutions and suspensions now contain 1 pound of their respective ingredients in each gallon of liquid.

Preparation of the mixture.—Follow the directions given below where 100 gallons of spray mixture can be made up and used at one time; for smaller amounts adjust the quantities used accordingly.

Provide two 50-gallon barrels with one head removed from each and with openings of ample size near the bottom head. The flow from the openings can be most easily controlled by attaching to them, with a pipe nipple, pieces of 1½ or 2 inch rubber hose just long enough to hook up to the tops of the barrels while they are being filled and stirred. Stir the concentrated solution and suspensions thoroughly and measure into one barrel 8 gallons of copper-sulphate stock solution and into the other 8 gallons of the lime suspension. Add to each enough water to make 47 gallons, stirring thoroughly. Provide a trough leading under the openings of the two barrels and emptying into the strainer of the spray tank. Lower the free ends of both pieces of hose, as nearly as may be, so that the diluted lime suspension and copper-sulphate solution flow at equal rates, mixing in the trough before entering the spray tank. While the mixture is flowing into the spray tank, slowly add 6 gallons of the rosin-fishoil soap suspension by pouring it into the spray-tank strainer in a small stream, so that the 6 gallons will be well distributed throughout the entire mixture. Do not let the soap come into contact with either of the other two ingredients until they have mixed. This method gives a thorough mixture of all the ingredients without the necessity for any hand stirring.

Do not put copper sulphate or Bordeaux mixture into tin or iron vessels. Use wood or copper containers.

A copper or bronze strainer of 18 meshes per inch should be used. Bordeaux mixture should be applied as soon as made, as it is not so good after settling.

Spray machines to be used.—The type of sprayer used must be decided for each individual case. Hand or power sprayers ordinarily used for potato and other vegetable spraying can be adapted to onions. A pressure of 100 pounds or more per square inch should be maintained, and a nozzle which will give a very fine spray is preferable.

PINK-ROOT

Pink-root is rapidly becoming one of the most serious onion diseases. Until recently it was confined in its severe form to the Bermuda onion sections of southern Texas. Its first noted appear-

ance in the Delta region of California in 1919 was followed by very heavy crop losses in 1921. In the North—although it has been found in New York, Indiana, Illinois, Wisconsin, Iowa, and Oregon—it has not as yet become a serious factor in onion production. Whether it will in the future become more aggressive under northern conditions is an important question.

CHARACTERISTICS OF PINK-ROOT

The symptoms become manifest in the seed bed or after transplanting. Affected roots shrivel and die and meanwhile take on a distinctly pink color. Abnormal yellowing of the roots is commonly associated with pink-root, but it may be due to other factors and is not necessarily a stage of this disease. As the plant sends out new roots they in turn eventually become diseased and functionless. This procedure continues throughout the growing season, and, although the affected plants are seldom killed by the disease, the reduced food supply results in merely scallions or small bulbs being formed. During the growing season there are often few outward symptoms of the disease. It becomes most apparent at harvest time by the small size of the bulbs, varying with the severity of the attack.

CAUSE OF PINK-ROOT

The fungus which causes pink-root (*Fusarium malli*) is closely related to the organisms associated with the Fusarium rot of the bulb scales. It lives and multiplies in the soil and consequently becomes the more destructive the longer onions are grown in the same field. It is spread on diseased green or bottom sets, on tools, and by natural agencies, such as surface drainage water. It attacks all varieties of onions, as well as shallot and garlic.

CONTROL OF PINK-ROOT

The control of pink-root is a very difficult problem when the soil once becomes infested. Diseased soil should be avoided for onion, shallot, or garlic culture. When the onion seed is sown in seed beds, clean soil should be selected. If this is not possible, the soil should first be sterilized by the steam-pan method.[3] Plants should never be transplanted from a diseased seed bed to healthy soil. In sections where the disease is known to be serious a long crop rotation should be practiced.

Field experiments by the Texas Agricultural Experiment Station show that factors tending to retard the growth of the plants are very favorable to pink-root. Some relief from the disease followed the application of fertilizers which would keep the plants in a vigorously growing condition. Indications are that high soil temperature favors the disease, and, where possible, adjustment of the planting date to avoid extremely high soil temperatures is advisable.

[3] For details of this method, see Farmers' Bulletin 996, entitled "Steam Sterilization of Seed Beds for Tobacco and Other Crops."

In the North, where the disease is still of minor importance, any outbreak should be reported to the State experiment station, and onion culture on the diseased area should be abandoned for several years.

FUSARIUM ROT

A rapid dying back of the leaves from the tips at the time when the plants are approaching maturity is commonly associated with the Fusarium rot affecting bulb. (See fig. 6.)

Most of the roots eventually become rotted off, and in their place a mass of white moldy growth is produced. The bulbs become soft, and on cutting them open one finds a semiwatery decay advancing from the base of the scale upward. The rot progresses rather slowly, and many of the recent infections are unnoticed at harvest time. The disease thus becomes a factor in transit and storage, where the decay may continue until the bulbs are entirely destroyed.

Reports of this trouble have come from Ohio, Illinois, Wisconsin, Colorado, and Washington, and it probably occurs in other States. It is caused by one or more species of soil fungi (*Fusarium* spp.), which invade the base of the bulbs, often following maggot injury.

Strict attention to sanitary conditions, careful sorting out of diseased bulbs at harvest time, and rotation of crops are the chief measures to be taken for the control of Fusarium rot.

LEAF-MOLD (BLACK STALK-ROT)

In midseason or later, dying back from the tips of the leaves commonly occurs. While this injury may be due in part to insufficient soil moisture, the trouble is often increased by a weakly parasitic fungus (*Macrosporium parasiticum*) which attacks the dying parts and later produces a black mold on the dead tissues. This fungus also commonly attacks the seed stalks, independently or following the mildew.

Although of widespread occurrence, the actual loss due to leaf-mold is of

FIG. 6.—An onion showing Fusarium rot. Decay starting at the base of the scales causes the leaves to die rapidly, and the bulb continues to rot in storage and in transit

minor importance, with the exception of the injury to the seed crops of Louisiana, California, and probably other sections. In this form it may cause severe damage, either independently or in conjunction with mildew. No satisfactory method of control has been perfected.

RUST

Two distinct rusts have been noted in America upon Egyptian perennial onions (*Allium cepa* var. *bulbellifera*). One, caused by the fungus *Puccinia porri*, has been noted in several instances in Connecticut. It appears in midseason on the leaves and seed stems as subcircular or elongated spots which split lengthwise and expose dusty orange-yellow spore masses. The other is caused by the common asparagus rust fungus (*Puccinia asparagi*), which occasionally goes over to the Egyptian onion when the latter is grown close to an infected asparagus patch. The disease appears on leaves and seed stems before midseason as light-yellow, roughly circular to oblong lesions, in each of which numerous spore cups, or æcia, eventually split the skin and expose the golden-yellow rust spores. In the case of the latter disease a species of Botrytis, very similar to or identical with one of those causing neck-rot of onion (see p. 20), commonly invades the seed stem through the rust lesions and causes girdling and lodging of the stem.

The first-named disease is apparently not of serious economic importance. The last-named trouble may be avoided by planting Egyptian onions at a considerable distance from asparagus.

WHITE-ROT, A EUROPEAN DISEASE

White-rot, a disease serious on onion and garlic and of minor importance on shallot and leek, has not as yet been authentically reported in America. It is known to be widespread in the British Isles and in Italy, and perhaps occurs in other countries of Europe. This fact is brought to the attention of growers and plant pathologists at this time because large quantities of onions and garlic are being imported from Europe annually and this disease may be introduced at any time, or in fact its introduction may already have occurred. Any outbreak of disease upon onion, garlic, or closely related plants answering to the following description [4] should therefore be reported and specimens of diseased plants mailed to the United States Department of Agriculture at once.

In England white-rot first appears late in May or early in June. The first signs are those of yellowing and wilting of the leaves, followed later by a total collapse of the top. The actual attack is made by the causal fungus (*Sclerotium cepivorum*), which inhabits the soil and invades first the roots and later the basal portions of the bulb scales. If diseased plants are gently pulled they will come up very readily, owing to the fact that the roots have been almost entirely destroyed. The diseased bulb is commonly covered with a white fluffy mass of fungous threads, and this is most pronounced in warm, damp weather. Somewhat later this fungous mass takes on the appearance of a closely fitting weft in which are embedded numerous black spherical bodies, or sclerotia, about the size of poppy seeds.

[4] This description of white-rot is adapted from the published accounts of two English scientists, Drs. A. D. Cotton and M. N. Owen.

The fungus continues to invade the bulb until it becomes shrunken and dried up.

In the early stages this disease might easily be confused with Fusarium rot (see p. 13), but in the latter no black sclerotia are ever formed. In the later stages white-rot may be mistaken for neck-rot (see p. 20). In the latter disease black sclerotia are commonly formed. The neck-rot sclerotia, however, are several times larger than those of the white-rot; moreover, a gray mold is commonly associated with neck-rot, while the mold associated with the other disease is distinctly white. Neck-rot almost always appears after harvest and starts in most cases at the neck. White-rot commonly appears in midseason or earlier, and infection occurs in the roots and bases of the scales.

DODDER

Dodder (*Cuscuta* sp.) belongs to the higher or green plants and differs from the above-mentioned fungous parasites in that it produces true flowers and true seeds. The seeds live over winter in the soil or are introduced in the spring with the onion seeds. The young dodder plant thus starts off just as the onion seedling does. It has no leaves and its tendril-like stem soon winds around the onion leaves and forms suckers, or haustoria, which invade the host tissue. (See fig. 7.) After having thus become established as a parasite the dodder gets most of its food from the onion and gradually sends out its tendrils to attack near-by plants. The final effect upon the onion is to kill the leaves prematurely and thus to prevent normal bulb development. The dodder continues to spread from original centers and by the end of the season roughly circular areas of considerable size may occur, in which the onion tops have been completely killed.

Dodder has been noted on onions in California, Washington, Illinois, and Wisconsin, and it is no doubt likely to occur in any onion section. It is not confined to the onion, but may attack a wide range of plants. Laborers commonly pick parts of dodder plants out of curiosity, carry them a short distance, and drop them. The parasite may then take new root and start a new center of infection. For this reason, when dodder first appears in the field it should be carefully removed, along with affected plants, and burned. Dissemination by laborers or by tools should be avoided, and the dodder plants should in no case be allowed to go to seed.

ROOT-KNOT[5]

Root-knot of onion is an eelworm disease which may be recognized by the spherical swellings or enlargements of affected roots, as shown in Figure 8. The above-ground parts of badly diseased plants are dwarfed, the leaves are a pale-green, sickly color, and the bulbs are reduced in size. Root-knot, while occurring as a serious trouble of many wild and cultivated plants in the southern portion of the United States, has been reported only occasionally on onions, and, fortunately, there is little likelihood that it will ever be a major disease of this crop. It is caused by a minute eelworm, or nematode (*Heterodera radicicola*), which lives in the soil and penetrates the

[5] This section on root-knot was prepared by Dr. L. P. Byars.

onion roots, where swellings are produced. After becoming mature in the roots, the nematode may lay hundreds of eggs, which hatch into active forms (larvæ), and thus complete the life cycle.

Soil once infested with the eelworms can be freed by the use of live steam applied under considerable pressure. In large areas where

FIG. 7.—Dodder, a parasite belonging to the higher green plants, attacking the onion. Note that the parasite has no leaves and obtains its food by sending "suckers" into the onion leaves, thus eventually killing them. Note, further, that dodder produces flowers and seeds in a manner similar to other green plants

steaming may not be practicable, the number of nematodes can be reduced by a proper system of crop rotation. By planting for two or more years on infested land crops which are not subject to nematode attack, the eelworms may be starved out to such an extent that a susceptible crop, such as the onion, will not be damaged seriously when planted in the soil.

To avoid root-knot it is advisable never to plant onions on land that is known to be infested.

For further details regarding the control of root-rot, see Farmers' Bulletin 648.

FARM PRACTICE IN RELATION TO STORAGE DISEASES

The interval of several weeks between harvest and storage or shipment is a very critical one with relation to the development of diseases in the warehouse or in transit. The care which is taken with the crop at this period may mean the difference between success and failure in carrying it through storage or in placing it on the market in good condition. The plant at this time has practically terminated its growth, and on going into its dormant state it becomes more susceptible to the attack of storage-rot fungi and bacteria, which are continually present in the soil and on dead refuse.

FIG. 8.—Onion root-knot, caused by an eelworm. Note that certain roots contain spherical swellings, from some of which small dark masses (the eggs) are protruding. Many active larvæ of the eelworm escape from these egg masses into the soil and render it unfit for growing onions as well as many other crops

While becoming dormant the bulbs must be allowed to "sweat" or cure preparatory to storage or shipment. For this purpose they are ordinarily placed in crates and stacked in the field or in open sheds, where the sunshine and air currents aid greatly in removing the moisture which is given off. Thus, if the weather remains clear and dry during harvesting and curing it, it is the common experience of growers that the crop will go through storage with small losses due to decay. Prevailing rainy weather, at this time, however, will almost invariably lead to heavy losses. The moisture is favorable for the development of the fungi and bacteria, and at the same time it delays harvest and prevents the proper maturing of the crop. Under such conditions certain storage diseases, such as neck-rot (see p. 20) and soft-rot (see p. 21), make considerable progress before the bulbs are pulled. On the other hand, high humidity of the atmosphere during the curing

period causes the moisture given off by the onions to accumulate in the crates, which favors the development of decays.

The control of storage diseases, therefore, will consist largely of attention to cultural methods based on the knowledge of these general facts. In view of this, the following specific recommendations are made with regard to the handling of the onion crop.

SANITATION

The organisms causing storage rots in general thrive on dead vegetable matter. Onion tops and diseased bulbs left on the field and onion refuse from the warehouse furnish excellent opportunities for these fungi and bacteria to multiply. The spores of certain of these organisms, especially those causing neck-rot (see p. 20), are readily carried long distances by the wind. A pile of rotting onions near the warehouse may thus be a means of infecting a crop a considerable distance away. All onion refuse left on the field should be raked and burned after harvest. Waste from the warehouse should be dumped in a remote place, or if spread on the fields it should be confined to those not to be used for the growing of onions.

FIG. 9.—Onion neck-rot. The softening and shriveling of the scales begin at the neck of the bulb, with the later development of black kernel-like masses on the surface

HARVESTING[6]

As soon as the neck of the onion bulb loses its stiffness sufficiently to allow the top to drop over readily the onion is ready to harvest. It is best to allow the tops to dry out as much as circumstances will permit before cutting or twisting, since this will help to reduce the trouble from storage rots. If the field matures unevenly it is well to start pulling when most of the plants have reached this stage. An unusual amount of rainy weather just previous to harvest may postpone the ripening and tend to cause an overproduction of scallions, or "stiffnecks." These should not be placed in storage, but sorted out and sold for immediate consumption. The cutting of the roots with a wheel hoe will tend to hasten the ripening of the tops. In clipping or twisting the tops a neck 1 or 2 inches long should be left, to avoid the exposure of the succulent tissue of the fleshy scales of the bulb. Care should be taken to avoid bruising the bulbs and thus opening the way for the organisms which cause decay. The milling of bottom sets before storage causes a certain amount of bruising and lowers the keeping quality.

REMOVAL OF DISEASED BULBS

It is essential that care be taken at harvest time to throw out all bulbs which show any signs of disease or insect injury. Although

[6] For more detailed information relative to horticultural methods of harvesting, curing, and storing onions, see Farmers' Bulletin 354, "Onion Culture."

smut (see p. 4) and mildew (see p. 8) do not of themselves cause decay, bulbs which have been attacked by these fungi are thereby made more susceptible to the invasion of storage-rot organisms. Fusarium rot (see p. 13), on the other hand, gains a start in the field and continues to injure the bulbs in storage. In unusually damp weather soft-rot and neck-rot may start in the field, and it is well to be on the watch for bulbs with softened necks at harvest time.

CURING

Onions are sometimes allowed to cure in windrows in the field; and if the weather is clear, yellow and red varieties can be handled successfully in this manner. It is preferable, however, to place them in slatted crates soon after topping and pile in open sheds or in stacks in the field. In the latter case the piles should be covered with temporary roofs for protection from rain. Exposure of white varieties (see p. 20) to damp weather in the field will almost invariably prove disastrous, and they should be placed in a curing shed, where advantage can be taken of clear weather and protection can be given during rainy periods.

STORING

In the Northern States onion warehouses should be built with the purpose in mind of keeping the temperature just above 32° F. during severe winter weather with as little artificial heating as possible. This necessitates walls and roof constructed to afford good insulating materials. Provision is necessary for ample ventilation, since the bulbs are continually giving off moisture which must be removed. This can be increased materially on clear days by opening doors and windows for a few hours. In very cold weather it is necessary to heat the house during this process, in order to prevent the freezing of the bulbs. A steam or hot-water heating system or stoves placed at intervals will be satisfactory. Large bulbs are stored in slatted bushel boxes or folding crates, while bottom sets should be placed 2 to 4 inches deep in shallow crates.

Where a modern warehouse is not available, a dry cellar which can be held at 32° to 35° F. can be used with good results.

RELATION OF VARIETIES TO STORAGE DISEASES

In the Northern States and on the Pacific coast, where Globe onions are grown most extensively, yellow and red varities are much less susceptible to decay in storage and transit. White varieties, on the other hand, are very subject to storage diseases, especially neck-rot and smudge, and they require much more care during harvest and curing in order to be handled successfully. In the onion bottom set-growing sections the same is true of the White Portugal, as compared with the Red Wethersfield, Yellow Strassburg, and Yellow Danvers. Certain white varieties, such as Queen, Pearl, and Barletta, are such poor keepers that they are seldom held in storage for any length of time.

In the onion regions of Texas, southern California, and Louisiana the Bermuda varieties are largely disposed of soon after harvest, on account of their poor keeping quality and the lack of cold-storage

facilities. In Louisiana the Creole variety is the favorite because it resists much more effectively than the white and yellow Bermuda varieties the attacks of fungi and bacteria in storage and in transit.

DISEASES PRIMARILY IMPORTANT IN STORAGE AND TRANSIT

NECK-ROT

Neck-rot is a destructive and widespread disease of onions in storage and in transit. During certain seasons many growers have lost 50 per cent or more of their crop on account of this trouble. White varieties are especially susceptible, but considerable loss is often sustained with red and yellow varieties.

FIG. 10.—Onion neck-rot. Longitudinal section of a diseased bulb, showing the outer scales badly rotted, while the disease is just appearing on the inner scales

CHARACTERISTICS OF NECK-ROT

Usually there is little or no evidence of this disease up to or at the time of harvest, but after the onions are topped and have lain in crates for a few days the early signs appear. A softening of the scales begins usually at the neck, more rarely at the base or at a wound.

There is a definite margin between the healthy tissue and the diseased portion, the latter taking on a sunken, water-soaked appearance. A gray feltlike growth later forms on the rotting scales, which may be accompanied by a gray to brownish mold, consisting of the spores (seeds) of the causal fungus, and by brown to black kernellike bodies (sclerotia) one-eighth to one-fourth inch in diameter (figs. 9 and 10). On red and yellow onions the pigment of the diseased portions is destroyed, while in the former the rotted tissues sometimes assume a pinkish tint. The disease may progress rather slowly unless conditions are very moist, several months often elapsing before the entire bulb is destroyed. The white varieties decay most readily, while the colored types more often escape it and when infected show a marked resistance to its progress.

CAUSE OF NECK-ROT

Neck-rot is a disease caused by one or more species of fungi (*Botrytis* spp.) closely related to the common gray molds which attack lettuce, cabbage, and numerous other vegetables. These fungi are not vigorous parasites and seldom seriously attack actively growing onion plants. They do not ordinarily penetrate the dry outer scale of the onion, but require a wound in order to gain entrance to the plant tissues. The gray to brown moldy growth on the rotten scales consists chiefly of the spores of the fungi, which are especially adapted to dissemination by air currents. They are thus carried to the healthy bulbs, where they germinate and send fungous threads

into the necks which have been wounded by the cutting or twisting of the tops. These threads then kill the tissue slightly in advance of their progress through the scale. The black kernellike bodies, or sclerotia, are compact masses of fungous threads, which, being resistant to cold and drought, serve to carry the organisms over winter.

CONTROL OF NECK-ROT

Proper care of the crop during harvest and curing is the chief measure of control for neck-rot (see p. 20). Avoid exposure to damp weather and provide cool, dry storage. White varieties should receive special attention, since they are very susceptible to the disease. Proper sanitation (see p. 18) is also very important and worthy of careful consideration in connection with this disease.

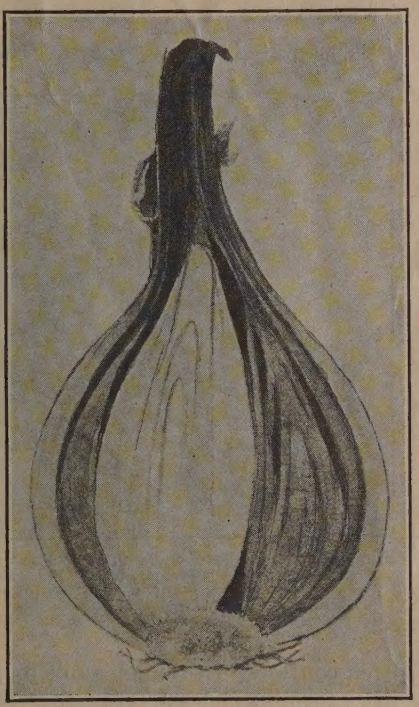

FIG. 11.—A section of an onion bulb showing bacterial soft-rot. This is a watery soft-rot, accompanied by an offensive odor, which starts usually at the neck and invades one or more scales, often leaving the outer scales intact

ARTIFICIAL CURING FOR THE CONTROL OF NECK-ROT

A rapid drying out of the neck of the bulb by means of artificial heat immediately after harvest is effective in the control of neck-rot. This is accomplished by passing a current of air heated to 100° to 120° F. over the onions in shallow crates until the necks are thoroughly dried. The threads of the causal fungus entering after the top of the bulb has been removed apparently require some moisture for their development, while thoroughly dried tissue offers a barrier to their progress. Experiments on a small scale have shown this to be a satisfactory method for the control of this disease. To apply this control on a commercial scale it is necessary to have a special kiln or a special room in the warehouse for this purpose. The temperature can be raised to 120° F. with safety. Provision should be made for a fairly rapid air circulation to carry off the moisture.

Experiments are under way with the object of devising the best methods for the application of this principle on a commercial basis.

SOFT-ROT

Soft-rot, being of bacterial origin, differs from other storage rots in the absence of fungous threads and spores, although it is sometimes followed by saprophytic fungi. The tissue first becomes glassy

or water soaked in appearance, and later disintegrates into a soft, watery mass. An offensive odor often accompanies the rot. The organism being unable to penetrate the unbroken scales, infection commonly takes place through the neck, often before the crop is harvested. When the rot affects only one or two inner scales, as is often the case (fig. 11), the only external sign of the disease is the lack of firmness detected on pressing the bulb between the fingers. Sunburn, freezing, and external bruises due to careless handling are followed very often by soft-rot, especially if the surfaces of the wounds remain moist.

CAUSE OF SOFT-ROT

Soft-rot is due to a group of bacteria[7] which cause soft-rots on cabbage, carrot, celery, and a large number of other vegetables. As a class they do not attack uninjured plants, and they require a wound and sufficient moisture to gain a foothold.

FIG. 12.—Onion black-mold. Compare its symptoms with those of onion smut. Note the irregular sooty masses on the outside of or between the scales, accompanied by the shriveling of the scales about the neck of the bulb, which gives them a brittle, papery texture

CONTROL OF SOFT-ROT

Crop rotation and sanitation should be thoroughly practiced to suppress the causal organisms. Precautionary measures already recommended (see pp. 18 and 19) with regard to harvesting, curing, and storing should be followed carefully. Sort out all affected bulbs before storage or shipment.

BLACK-MOLD

Because of its resemblance in appearance, black-mold is often confused with onion smut by growers and dealers. The chief distinguishing characteristic is the fact that the black powdery masses of spores in the case of black-mold are borne on the exterior of the scales and can be rubbed off readily (fig. 12). It is true that the disease is not confined to the exterior of the bulb, but as the inner scales are separated, the black powder will be found to exist on the exterior of the individual scales. Onion smut, on the other hand, as seen in storage or market, is characterized by oblong or linear brown or black lesions, most commonly near the base of the bulb and as deep as the third or fourth scale. Black-mold causes a slow shriveling of the affected scale, which assumes a brittle texture. Moist conditions favor the disease, while a cool, dry environment seems to check it.

Black-mold occurs to some extent in northern onion sections, but it is of slight economic importance there. In Louisiana, Texas, and

[7] *Bacillus carotovorus* is an example of this group.

California, however, it is one of the most important storage and transit diseases.

CAUSE OF BLACK-MOLD

Black-mold is caused by fungus (*Aspergillus niger*) which is a common organism living on almost any dead or dying vegetable matter. Where it is most serious on onions it undoubtedly grows and multiplies throughout the year in the soil or on dead refuse. It is present to a slight extent on the dead outer scales of the bulbs before harvest, but is not noticeable until the onions are pulled. Rainy weather at this critical period will result in a widespread infection which continues to develop in storage or transit.

CONTROL OF BLACK-MOLD

General sanitary measures and protection from moisture after harvest are essential. The bulbs should be thoroughly dry before they are shipped, since moisture favors the rapid development of the disease in transit. Dealers in northern markets receiving infected lots to be held any considerable length of time before consumption should transfer them to cold storage in order to hold the disease in check.

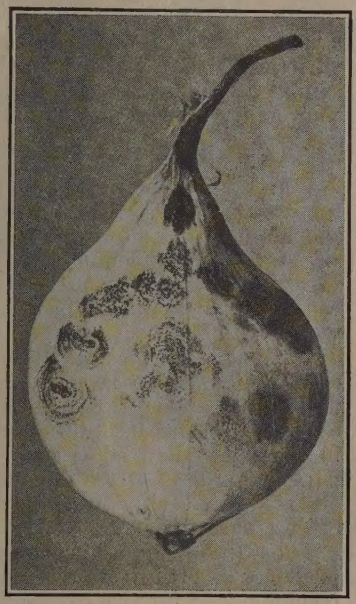

FIG. 13.—Onion smudge. Note the smudgy spots made up of small black dots. The disease is confined largely to the outer scales of white varieties.

SMUDGE (ANTHRACNOSE, BLACK-SPOT)

Onion smudge is confined largely to white varieties. It appears in the field just before harvest time and continues to develop during the storage period. It is characterized by small dark-green to black dots which appear on the outer scales. These small dots may be grouped together in various ways and are often arranged in concentric rings, giving a smudgy, unsightly appearance to the white bulbs (fig. 13). The fungus ordinarily attacks the fleshy scales only mildly and in such cases does not cause any appreciable shrinkage in storage, its chief damage being the reduction of the market quality of the crop. However, after rainy weather during harvest, when the bulbs are crated and stored without being dried and cured thoroughly, the disease causes considerable loss.

CAUSE OF SMUDGE

Smudge is caused by a fungus (*Colletotrichum* (*Vermicularia*) *circanans*) which lives over winter on onion scales in the soil or on bulbs in the warehouse, and consequently it increases in amount where onions are grown on the same fields year after year. It is widely distributed through the trade on white-onion sets, and by

this means is introduced into soil new to onions. Under favorable conditions the fungus attacks the outer scales and forms many small black dots on which myriads of minute spores are produced (fig. 13). These spores may be carried away in drops of water to other onion scales, where they germinate within a few hours and renew their attack. The fungus passes through this whole life cycle within a few days when the weather is warm and moist. A little disease in the field before harvest will furnish spores enough to spot the bulbs very badly if a few days of moist weather should come during harvest or while the crates are stacked in the field.

CONTROL OF SMUDGE

Since the development of the disease is dependent largely on abundant moisture, special care is needed in handling the white varieties. Harvest the crop without delay, avoiding any exposure to rain if possible. Stack in an open shed and allow the onions to cure thoroughly. Place white sets in thin layers in shallow crates.

MACROSPORIUM ROT

White onions are occasionally affected with a decay distinct from those already described. The causal fungus is a species of Macrosporium distinct, however, from that causing leaf-mold. The parasite enters most commonly through the wounded neck, but may invade other wounds on the fleshy scale. The decay is at first semi-watery in nature, but is made more noticeable by the color associated with it. The parasite secretes in abundance a pigment which is diffused through the scale tissue somewhat in advance of the fungous threads. Affected tissue is thus deep yellow at first, turning gradually to a wine red. Eventually it becomes dark brown to black, owing to the profuse development of dark-colored fungous threads in the older decayed tissue. Diseased scales later dry down to a papery texture. Often only one or two outer scales are affected. In other cases, notably those of white bottom sets, the entire bulb may be destroyed.

The causal fungus probably lives over winter in the soil. The practices described for the control of onion neck-rot (see p. 21) are recommended for this disease.

SUMMARY OF CONTROL MEASURES

Control onion smut by applying formaldehyde solution (1 pint to 16 gallons at the rate of 200 gallons per acre) by means of a drip attachment on the seeder.

Control blight by avoiding excessive soil moisture, by crop rotation, and by thorough cultivation. If spraying is to be practiced, it should be done early and thoroughly.

Reduce pink-root by avoiding diseased soil, especially for seed beds; rotate onions with other crops; use quick-acting fertilizers if the disease appears.

In general, storage diseases are to be controlled by the practice of sanitary measures, the sorting out of diseased bulbs at harvest, protection from rain after harvest, thorough curing, and storage in a dry, well-ventilated warehouse at 32° to 35° F.

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